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DISTRIBUTION OF COLORS AMONG THE STARS OF N. G. C. 1647 AND M 67

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Recent investigations have given the colors of a considerable number of stars in two of the moderately large and open clusters, and it is of interest to examine the results for peculiarities of distribution and frequency. Although the data are slender, several points are revealed with some clearness.

N. G. C. 1647

The data for N. G. C. 1647 consist of effective wave-lengths for 184 stars determined by Hertzsprung.¹ Directly observed color indices² are also available for about 50 of these objects, but, as the two series of results are in close agreement, the discussion is based upon the effective wave-lengths alone. The following correspondences between color class³ and effective wave length were established:

Effective Wave-Length.....	4190	4260	4330	4400	4470	4540A
Color Class.....	<i>b</i> 0	<i>a</i> 0	<i>f</i> 0	<i>g</i> 0	<i>k</i> 0	<i>m</i> 0

Counts within six 5'-zones gave the results in Table I, which shows the number of stars of each color within each zone, and also the totals, the relative areas of the zones, and the densities per area of 25 π sq. min. of arc.

TABLE I
Color and Distance—Number of Stars in N. G. C. 1647

COLOR	ZONE						TOTALS
	0'-5'	5'-10'	10'-15'	15'-20'	20'-25'	25'-30'	
<i>b</i>	2	4	5	1	1	1	14
<i>a</i>	8	15	16	4	9	12	64
<i>f</i>	12	10	14	14	7	13	70
<i>g</i>	0	3	4	3	4	3	17
<i>k</i>	0	0	4	1	7	0	12
<i>m</i>	1	1	1	1	1	2	7
Totals.....	23	33	44	24	29	31	184
Relative area...	1	3	5	7	9	11	36
Density.....	23.00	10.99	8.80	3.43	3.22	2.81	—

A comparison of the totals for the three inner zones (N_1) with those for the three outer (N_2) suggests that the condensation may vary with

the color (second, third, and fourth columns, Table II). But the background stars, as well as the members of the cluster, are included, and it does not follow that for the cluster itself the condensation is variable.

Let us assume for a moment that the ratio n_1/n_2 for the cluster alone does not vary with the color. Its value must then be approximately that of N_1/N_2 for the b and early a stars, for it is probable that all these belong to the cluster.⁴ As a round number, we may assume $n_1/n_2 = 3$.

TABLE II
Percentage of Colors in N. G. C. 1647 and Background

COLOR	TOTAL NO. STARS		N_1/N_2	n	TOTAL NO. STARS		PERCENTAGES		
	0'-15'	15'-30'			Cl.	Bkgd.	Cl.	Bkgd.	Other Reg.
<i>b</i>	11	3	3.7	-0.25	15	-1	14	-1	1
<i>a</i>	39	25	1.6	4.50	46	18	43	24	13
<i>f</i>	36	34	1.1	8.25	37	33	34	43	47
<i>g</i>	7	10	0.7	2.88	5 ⁵	11 ⁵	5	15	30
<i>km</i>	7	12	0.6	3.62	4 ⁵	14 ⁵	4	19	9
Totals.....	100	84		19.00	108	76	100	100	100

The number of background stars, n , can then be calculated for each color by

$$\frac{N_1 - n}{N_2 - 3n} = 3,$$

for which the unit of area is 225π sq. min. The results are in the fifth column of Table II. The numbers for the cluster and the background can now be separated; their values are in the sixth and seventh columns. The percentage distribution of colors is in the two following columns. The last column shows the corresponding mean distribution for two other regions of the sky, namely, the North Pole and that of S Cygni.⁴

The background percentages were calculated on the assumption that the condensation within the cluster is the same for all colors; their agreement with the values in the last column of Table II is close enough to give some validity to that assumption. At any rate, there is no evidence for supposing that the distribution within the cluster depends upon the color.

An examination of the distribution from the standpoint of distance and brightness suggests a relatively greater condensation of the brighter stars; but from 10.5 downward the distribution seems to be the same for all magnitudes.

The apparent magnitude corresponding to maximum frequency is, however, quite different for the different colors, as Hertzsprung has already pointed out¹ and as appears from the results in Table III. From these it is seen that the magnitude at which maximum frequency occurs increases by about two magnitudes for an increase in the color of one color class. If an extrapolation of this result is to be permitted, one would infer that the majority of the *g*, *k*, and *m* stars belonging to the cluster are so faint that they do not fall within the limits of the available data. This probably accounts for the relatively small percentage of these colors found among the cluster stars. (See eighth column, Table II.)

Inasmuch as there are no reliable data for the distribution of the background stars, with respect to color and magnitude, these objects

TABLE III
Color and Magnitude—Number of Stars in N. G. C. 1647

MAG.	COLOR						TOTAL
	<i>b</i>	<i>a</i>	<i>f</i>	<i>g</i>	<i>k</i>	<i>m</i>	
<9.5	5	0	0	0	2	0	7
9.5–10.5	8	11	0	1	1	0	21
10.5–11.5	0	13	3	0	0	1	17
11.5–12.5	1	25	6	1	0	1	34
12.5–13.5	0	8	26	3	0	2	39
13.5–14.5	0	8	34	12	9	2	65
> 14.5	—	—	—	—	—	1	1
Totals.....	14	65	69	17	12	7	184

are necessarily included in the conclusions stated in the two preceding paragraphs.

MESSIER 67

The data consist of 231 color indices derived by Shapley with the 60-inch reflector. The distribution for color and distance is shown in Table IV. The densities in the last line indicate that here the counts have been extended beyond the boundary of the cluster, and that from 7'.5 outward the tabulated stars belong to the background.

We have, therefore, in this instance, an approximation for the constitution of the background in the direction of the cluster. After deducting the background stars and combining the results for the cluster into two zones, we find the numbers in the second and third columns of Table V. The totals for the cluster and the background, and the percentage distribution are in the remainder of the table. The percent-

ages for the background are in reasonably good agreement with those for the North Pole and the region of S Cygni given in the last column. There is no evidence of a variation of the condensation with color either before or after the deduction of the background stars.

The distribution with respect to magnitude and distance, and magnitude and color, is similar to that for N. G. C. 1647, although the color and magnitude relation is less clearly marked than was the case with that cluster.

TABLE IV
Color and Distance—Number of Stars in M 67

COLOR	ZONE						TOTALS
	0-1'.5	1'.5-3'.5	3'.5-5'.5	5'.5-7'.5	7'.5-9'.5	9'.5-11'.5	
<i>a</i>	0	2	2	0	1	1	6
<i>f</i>	5	10	9	15	11	24	74
<i>g</i>	8	39	34	22	12	14	129
<i>k</i>	2	7	9	2	1	1	22
Totals....	15	58	54	39	25	40	231
Relative area...	2.25	10	18	26	34	42	132.25
Density....	6.67	5.80	3.00	1.50	0.73	0.95	

TABLE V
Percentage of Colors in M 67 and Background

COLOR	CLUSTER ALONE		TOTALS		PERCENTAGES		
	0'-3'.5	3'.5-7'.5	Cl.	Bkgd.	Cl.	Bkgd.	Other Regions
<i>a</i>	2	1	3	3	3	3	13
<i>f</i>	9	4	13	61	11	54	47
<i>g</i>	43	42	85	44	71	40	30
<i>k</i>	9	9	18	4	15	4	9
Totals.....	63	56	119	112	100	101	99

SUMMARY OF RESULTS

1. Neither N. G. C. 1647 nor M 67 show any dependence of condensation upon color which cannot be explained on the basis of included background stars.

2. With the possible exception of an excess of a few bright stars in the center of N. G. C. 1647, there seems to be no dependence of condensation upon magnitude.

3. There is a marked relation between color and magnitude in N. G. C. 1647; the connection is also evident, though less pronounced, in the case of M 67.

4. The probable distribution of colors in the background of N. G. C. 1647, and that actually observed for M 67, is similar to that for the North Pole and the region of S Cygni.

5. In neither case is the limiting magnitude low enough to include all the cluster stars; but as far as these limits, the percentage distribution of the different colors in the cluster is notably different from that in the background; moreover, there is a marked difference for the two clusters. N. G. C. 1647 contains a considerable number of *b* and *a* stars, and practically none of the *g*, *k*, and *m* classes, except as they may be fainter than the limiting magnitude. M 67, on the other hand, shows no *b* and only 3% of *a* stars. The maximum frequency of 71% is for *g* and, curiously enough, no *m* stars appear.

¹ *Mt. Wilson Contr.*, No. 100; *Astrophys. J.*, **42**, (1915).

² *Mt. Wilson Contr.*, No. 102; *Astrophys. J.*, **42**, (1915).

³ A Notation for Use in the Discussion of Star Colors, these PROCEEDINGS, **1**, 481 (1915).

⁴ *Mt. Wilson Contr.*, No. 81; *Astrophys. J.*, **39**, 361 (1914).

ON THIELE'S 'PHASE' IN BAND SPECTRA

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In the emission spectra of all compounds and of many elements the lines start abruptly at a certain wave-length, near which they are very close together, and separate more and more as the distance from the beginning or 'head' is increased. Such spectra are called band or channeled spectra because, with relatively small dispersion, they have the general appearance of the chiaro-oscuro of a channeled column illuminated laterally. One of the problems of spectroscopy consists in finding the law governing the relative frequencies of the lines of one band or of a group of bands. In other words, the problem is to arrange the lines in series and to express their frequencies by a mathematical formula, as has been done for a fairly large number of line spectra. The analysis of a line spectrum into series is greatly facilitated and made secure by the fact that lines of the same series show their functional relationship by the similarity of the changes which they undergo when the source is subjected to pressure, or is placed in a magnetic field, etc. On the other hand, the frequencies of the lines of the majority of well-developed band spectra do not exhibit the pressure and Zeeman effects. Consequently, since physical criteria are lacking, the grouping into series of the lines of band spectra depends wholly upon the